IASI* Product Generation, Products, and Data Access

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EUMETSAT

*Infrared Atmospheric Sounding Interferometer
Metop - fully integrated
IASI Level 2 Product Generation
High Level Break-Down

- IASI Level 1c
- AVHRR Cloud Mask and S/CTT
- Configurable Databases
- ATOVS Level 2
- AMSU-A Level 1
- MHS Level 1
- NWP Forecast

Pre-Processing

Cloud Processing

Geophysical Parameters Retrieval

Monitoring Information
Level 2 Product
Quality Information
Instruments' Fields of View
Mapping of AVHRR to IASI IFOV
Properties of the Operational IASI L2 Processor (1/3)

• For a best use of IASI measurements the level 2 processing can combine IASI with concurrent measurements of AVHRR, AMSU-A, MHS, and ATOVS Level 2 products

• IASI stand-alone processing is possible if other measurements are not available, or if Product Processing Facility is explicitly configured to exclude other instruments

• NWP forecast is included to provide surface pressure as reference for the profiles to be retrieved and surface wind speed over sea for the calculation of surface emissivity

• Optionally, the NWP forecast profiles of temperature, water vapour and ozone can be used to initialise and/or constrain the retrieval
Properties of the Operational IASI L2 Processor (2/3)

• Processing is steered by configuration settings (80 configurable auxiliary data sets), which allow for optimisation of the Product Processing Facility before and during commissioning.

• Online quality control supports the choice of best processing options in case of partly unavailable IASI data or corrupt side information (data from other instruments or NWP forecast).

• Besides error covariances a number of flags are generated steering through the processing and giving quality indicators; 40 flags are specified, which are part of the product.
Cloud Processing

- Cloud detection
  - AVHRR-based cloud detection using Scenes Analysis from AVHRR Level 1 processing
  - Combined IASI / ATOVS cloud detection
  - IASI stand-alone cloud detection

- Cloud parameters retrieval
  - Cloud fraction
  - Cloud top height
  - Cloud phase
Clear and Cloudy IASI Spectra

Clear

Cloudy

$T_b (K)$

$\nu \text{ (cm}^{-1}\text{)}$
Discrimination between Ice and Water Clouds

![Graph showing the discrimination between Ice (Ci) and Water (As) clouds. The graph plots temperature (T_b in K) against spectral frequency (ν in cm⁻¹). The graph highlights the distinct spectral signatures of ice and water clouds, allowing for their differentiation in remote sensing applications.]
Geophysical Parameters Retrieval

State Vector to be Retrieved

- The state vector to be retrieved consists of the following parameters
  - Temperature profile at a minimum of 40 levels
  - Water vapour profile at a minimum of 20 levels
  - Ozone columns in deep layers (0-6km, 0-12 km, 0-16 km, total column)
  - Land or sea surface temperature
  - Surface emissivity at 12 spectral positions
  - Columnar amounts of N₂O, CO, CH₄, CO₂
  - Cloud amount (up to three cloud formations)
  - Cloud top temperature (up to three cloud formations)
  - Cloud phase

- In case of clouds and elevated surface the state vector has to be modified

- The level 2 product contains the state vector along with information on quality and processing options and compressed error covariance
Geophysical Parameters Retrieval
First Retrieval

• Spectra PC scores regression for temperature and water-vapour, and ozone profiles, surface temperature, and surface emissivity

• Artificial neural network (multi-layer perceptron) for trace gases (optionally also for temperature, water-vapour and ozone, depends on configuration setting)

• The results from the first retrieval may constitute the final product or may serve as input to the final, iterative retrieval; the choice depends on configuration setting and on quality of the first retrieval results
Retrieval Simulation:
Example for Single Retrieval
Arctic Atmosphere

Truth
Retrieval
Retrieval Simulation:
Example for Single Retrieval
Mid-Latitude Atmosphere

Truth
Retrieval
Final, Iterative Retrieval

• Simultaneous iterative retrieval, seeking maximum probability solution for minimisation of cost function by Marquardt-Levenberg method, using a subset of IASI channels, combined to super-channels

• Initialisation with results from first retrieval

• Other choices of initialisation may be selected, depending on configuration setting and availability (e.g. NWP forecast, climatology, ATOVS Level 2 product)

• Background state vector from climatology, ATOVS Level 2 product, adjacent retrieval, or NWP forecast, depending on configuration and availability

• State vector to be iterated depends on cloud conditions and configuration setting (clear, cloudy, variational cloud clearing)
Super-Channel Composition

• Search for highly correlated radiances among all IASI spectral samples (noise-normalised radiances) and collect them in clusters
  — No need to have adjacent spectral samples
  — Correlation must be pre-determined at certain level: determines the number of clusters

• Determine a lead channel in each cluster: Radiance and Jacobians will only be calculated for lead channel radiances \( y_L(x) \)

• Represent the measured radiance \( y_L^m \) of a cluster by a weighted average of all radiance samples which are members of the same cluster
  — Weights consist of regression coefficients, taking into account the correlation and the noise of the respective sample
  — Errors include measurement and regression errors

\[
y_L^m = \frac{1}{N} \sum_{i=1}^{N} a_i + b_i y_i^m
\]
Radiative Transfer Simulations and Super-Channel Clustering

- For a set of 53980 situations RTIASI-5 simulations have been carried out, assuming a random selection of possible scan angles.

- The resulting radiance spectra (apodised) have been normalised with the corresponding noise.

- A correlation analysis is done between spectral samples:
  - All samples with a correlation higher than a threshold are retained in the respective cluster.
  - The assumed thresholds vary between 0.95 and 0.999.

- The lead sample is regressed against all other member samples of a cluster to obtain weighting coefficients and error estimates.
# Super-Channel Properties

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<th>Number of Super-Channel Clusters</th>
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<tr>
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<tr>
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</table>
Population of Super-Channel Clusters

Correlation = 0.99, 222 Super Channels

Correlation = 0.995, 417 Super Channels

Correlation = 0.999, 1633 Super Channels
Spectral Range Covered by Super-Channel Clusters
Population of Super-Channel Clusters and Noise Reduction

Correlation = 0.99, 222 Super Channels
Examples of Super-Channel Clusters

Correlation: 0.995

Cluster 6:
15 samples
Lead: 647 cm⁻¹

Cluster 3:
36 samples
Lead: 645.75 cm⁻¹
The retrieval schemes have been tested extensively with real AIRS data and compared to co-located ECMWF forecasts and radiosonde measurements, focusing on temperature and water-vapour retrievals.

Modification of the processing scheme:

- Replacement of RTIASI by RTTOV-8 or SARTA in variational retrieval
- Bias correction (additive constant per channel) based on global set of RT forward calculations with ECMWF forecast and co-located AIRS
- Modification of EOF regression coefficients: adaptation to AIRS spectral and radiometric characteristics
- Use of all “good” AIRS channels in first guess and variational retrievals, i.e. excluding black-listed channels with excessive noise characteristics
- Adaptation of cloud detection schemes

Case studies in clear and cloudy situations with data from the EAQUATE campaign in summer 2004.
EAQUATE Radiosonde Locations

- MSG Ch 9
- 8 August 2004, 01:12 UTC

Zadar
Pratica Di Mare
Trapani

- AIRS 01:09
- SONDES 00:00
- ECMWF 00:00
Inter-Comparison: Trappani

- EOF first guess
- No background
- Physical constraint
- 69 minutes time difference
Inter-Comparison: Zadar

- EOF first guess
- No background
- Physical constraint
- 69 minutes time difference
Test with AIRS Data: Results

- Difference in retrieval performance using RTTOV or SARTA can be removed by appropriate bias correction
- Initialisation of variational retrieval with results from first retrieval yields better retrieval performance than initialisation with climatology
- Climatology as background leads to results strongly biased towards climatology and prevents the detection of fine structure
- Physical constraints towards sub-adiabatic temperature profiles and non-saturated humidity profiles provide good performance
- First guess is important for variational retrieval, the EOF regression is already highly performing
- Introduction of a proximity constraint requiring the variational retrieval to stay close to first guess provides best results
IASI Data Transmission and Processing

• Satellite to ground transmission:
  — On-board storage and direct broadcast to local users
  — Down-link of global data to Svalbard receiving station after each completed orbit
  — Transmission of data to EUMETSAT Headquarters at Darmstadt

• Data processing at EPS Core Ground Segment:
  — Generation of Level 1 products (decommutation, calibration, apodisation, geo-location, and mapping of imagery)
  — Generation of Level 2 products (geophysical parameters)

• Distribution to users:
  — Near-real time transmission of products to users (Level 1: 2.25 hours, Level 2: 3 hours) via satellite broadcast (EUMETCast)
  — Distribution of sub-sampled data (spatially, and spectrally in case of L1) via GTS to WMO users (same timeline as NRT transmission)
  — Storage in Unified Archival and Retrieval Facility (UMARF) for later access by users (7 hours after measurement)
Timeline for IASI Data Validation

- Metop-A launch: 17 July 2006
- IASI switch-on: 21 July 2006
  - Followed by CNES Cal/Val Phases A and B
  - A: Instrument activation and evaluation/system technical evaluation
  - B: Early validation of Level 1 products
- First IASI measurements: 31 August 2006
- Reference orbit for off-line testing available: 2 December 2006
- Early Level 1 products available: 28 December 2006
- CNES Cal/Val Phase C: In-depth validation of Level 1 Products
- Completion of Level 1 validation: 10 March 2007
- Start of Level 2 validation: 29 January 2007
- Completion of Level 2 validation: 21 May 2007